Synoptic Estimates of Waves and Currents via Real-Time Assimilation of In-Situ Observations

PI Merrick C. Haller
202 Apperson Hall, Oregon State University, Corvallis, OR 97331-2302
phone: (541) 737-9141 fax: (541) 737-0485 email: hallerm@engr.orst.edu

Award Number: N00014-02-1-0147
http://ccee.oregonstate.edu/people/faculty/ocean/merrickhaller.html

LONG-TERM GOALS

The long term goal of this effort is to develop an improved nearshore wave and current modeling system in order to achieve better and more detailed short-term predictive estimates of nearshore oceanographic conditions over spatial scales on the order of kilometers and time scales of the order hours to days.

OBJECTIVES

The overall objective of this project component is to support the integration of a variational data assimilation capability into the nearshore wave and current model based on the extended-Boussinesq equations of Wei *et al.* (1996). The variational assimilation algorithm is being developed by Dr. Dave Walker at General Dynamics (Ann Arbor) under a separate award (N00014-00-D-0114-0007). The focus of the effort under the present award over the past year has been on identifying improvements in model physics that may be necessary for the success of data assimilation procedures.

APPROACH

Over the past year we encountered some road blocks in the development of the field-scale MPI Boussinesq code that we were working with. The difficulties in implementing a wavemaker capable of generating an accurate representation of measured 2D directional wave spectra were particularly troublesome. There have also been issues with stability problems in transitioning the code from a Linux Beowulf platform to a Sun Sparc platform. Since these difficulties were severely restricting concrete progress, we instead have concentrated on the accuracy of the wave breaking parameterization used in the FUNWAVE Boussinesq code (Wei *et al.*, 1996; Kennedy *et al*., 2000; Kirby, 2003). This is a necessary component of the work because assimilation algorithms may be sensitive to wave breaking parameterizations, especially when surf zone data is used for assimilation. The wave breaking process is highly nonlinear and it is unclear how well surf zone information will be transmitted through the breaker line back to the boundaries during the assimilation process.

Our approach to the wave breaking study is to compare the predictions of wave breaking from the phase-resolving FUNWAVE model with observations made by the newly installed ARGUS-III system (site “tsue”; http://cil-www.coas.oregonstate.edu:8080/) at the O.H. Hindsdale Wave Research Laboratory (WRL, http://wave.oregonstate.edu/). This approach is new for two reasons, first by using a laboratory facility of this size we are able to control our wave conditions and still operate at large scales; secondly, performing the analysis on a wave-by-wave basis (as opposed to the time exposure

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2004**	2. REPORT TYPE	3. DATES COVERED **00-00-2004 to 00-00-2004**

4. TITLE AND SUBTITLE **Synoptic Estimates of Waves and Currents via Real-Time Assimilation of In-Situ Observations**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Oregon State University,,202 Apperson Hall,,Corvallis,,OR,97331**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

approach) is also new. The experiments were performed by a graduate student (Patricio Catalan) who I am advising along with the staff at the WRL and the Coastal Imaging Lab. Patricio is partially funded through a Fullbright scholarship, with supplemental stipend funds supplied from the present project. The experiments were funded through other support (NSF-REU and internal funds).

WORK COMPLETED

A complete set of large scale laboratory experiments were performed encompassing a range of wave conditions, including both regular and irregular waves. For each of the 20 runs we collected wave gage data from 6 in-situ wave gages along with 3 cross-shore video pixel transects that spanned the entire region of interest. The wave gages were sampled at 50 Hz and the video pixels were sampled at 10 Hz. The number of runs and experimental conditions are listed in Table 1.

Table 1: Table of experimental conditions for the lab experiments.

# of runs	Offshore Waveheights (m)	Period (sec)	Regular vs. irregular waves
2	0.60,0.60	2.7	Reg.
4	0.60,0.40,0.60,0.4	4.0	Reg.
2	0.50,0.50	5.0	Reg.
2	0.5,0.5	6.0	Reg.
2	0.40,0.40	8.0	Reg.
2	0.60,0.6	2.7	Irreg.
4	0.60,0.40,0.6,0.4	4.0	Irreg.
2	0.50,0.50	5.0	Irreg.

Sample rectified video images from the Argus cameras showing the region of interest are shown in Figure 1. The underlying barred bathymetry is shown in Figure 2 along with the location of the in-situ wave gages. In addition to collecting the data, we have also begun the basic data analysis and have made several model runs to begin model/data comparisons. Initial results are given in the following section.

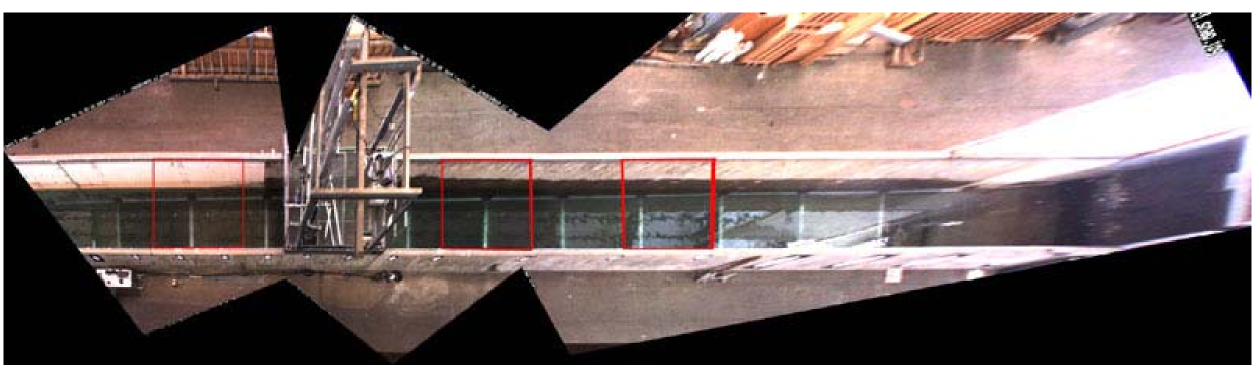

Figure 1: Merged and rectified image of the Long Wave Flume from cameras 1, 2, and 3. Wavemaker is to the left of the image (not shown) and shoreline is on the right.

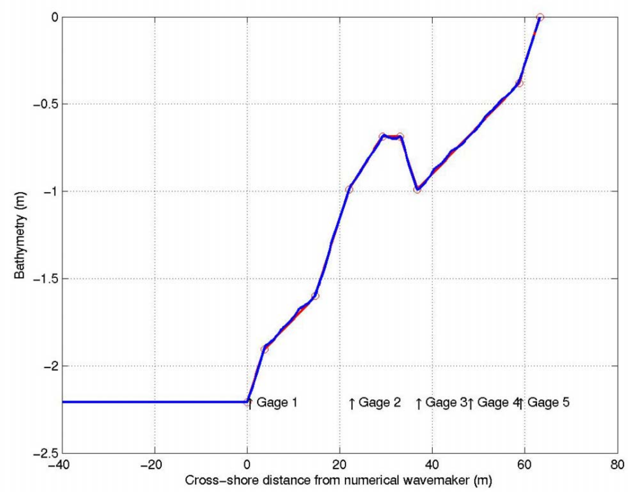

Figure 2: Barred beach profile (fixed bed) used in the experiments, fixed wave gage locations are noted at bottom. Note, in this figure the x-axis has been offset so that the shoreline is at ~x=62 m.

RESULTS

The FUNWAVE model is forced at the offshore boundary by the time series of water surface elevation measured at the offshore wave gage (gage 1) for each run. Typically wave model accuracy and wave dissipation parameterizations are tested simply by comparing mean (or rms) wave height transformation across the domain. However, comparisons of wave breaking evolution for individual waves are a much more rigorous test of the model, and are expected to be sensitive to the shape of individual waves. Hence, we first compare the water surface time series predictions to the data recorded at the inshore wave gages. Figure 3 shows time series comparisons for one experimental run. Initial comparisons have shown good model agreement for most wave conditions with the largest differences occurring very close to the shoreline.

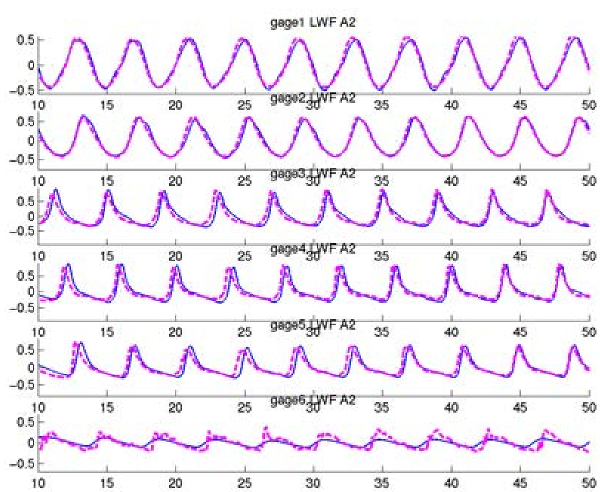

Figure 3: Measured time series of water surface elevation from FUNWAVE (solid) and in-situ gages (dashed).

The video data set that was collected is quite large. Each of the 20 experimental runs were 10 to 20 minutes in length and were continuously sampled at 10 Hz along 3 separate cross-shore pixel transects. The spatial pixel spacing was ~5 cm and each transect was ~ 50 m long. So there is a lot of data to analyze.

The top half of Figure 4 compares the measured mean wave heights with those predicted by the model, and the model/data agreement is generally good; although the model predicts breaking at the shoreline to occur earlier than was observed. A simple comparison between the time-averaged wave breaking dissipation predicted by the FUNWAVE model (breaking eddy viscosity) and the video intensity (a proxy for dissipation) measured by the cameras is shown in the bottom half of Figure 4. The data show that for the long term average there is a significant cross-shore offset between the peaks in model dissipation and video intensity. The figure also indicates that the peak in the video intensity occurs shoreward of the bar crest. This result appears to be different to what has been found in the field. Typically, the video intensity maximum is shifted offshore of the bar crest due to the relict foam that is found in this area (van Enckevort and Ruessink, 2001). It remains to be seen why it is different in this case and it is likely that a wave-by-wave analysis will provide more insight.

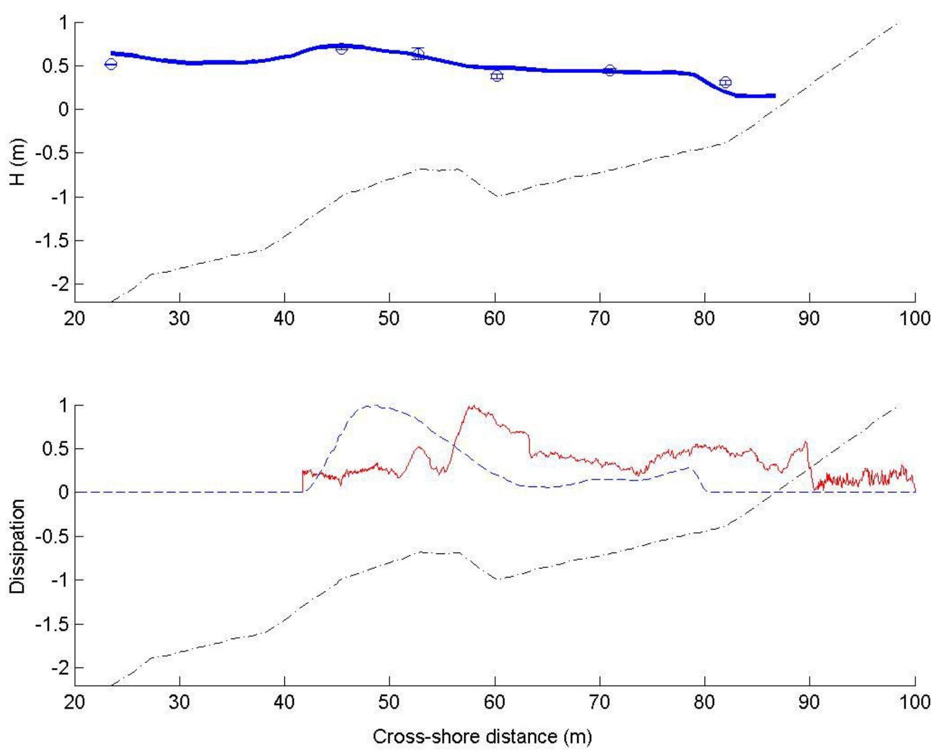

Figure 4: (top) Measured mean wave height from one experimental run (circles), modeled wave height (solid line), fixed bathymetry (dashed); (bottom) time-averaged breaking eddy viscosity from FUNWAVE (dashed) time-averaged video intensity (red).

Some of our initial results regarding the evolution of individual shallow water breaking waves are shown in Figure 5. One model/data comparison we wish to make regards the cross-shore size of the region of active breaking (whitewater). This cross-shore distance represents the size of the bore or "bore width". Both the FUNWAVE output and the video observations were processed to extract the bore width of a single wave. Tracking the bore width for a single wave as it propagates through the surf zone represents a single realization of a somewhat random process. Thus for monochromatic test conditions we may wish to phase-average the results to reduce random variability.

The bore widths (derived from the video observations) as a function of cross-shore distance for both an individually tracked wave and a phase-averaged wave are shown as the blue lines in Figure 5. The figure shows that the two results are not significantly different. The phase-averaged results from the FUNWAVE output show interesting differences from the observations. In contrast to the observations, the model dissipation is applied over a fairly constant portion of the front face of the wave, and the dissipation ramps up quickly over the bar and shuts off quickly after.

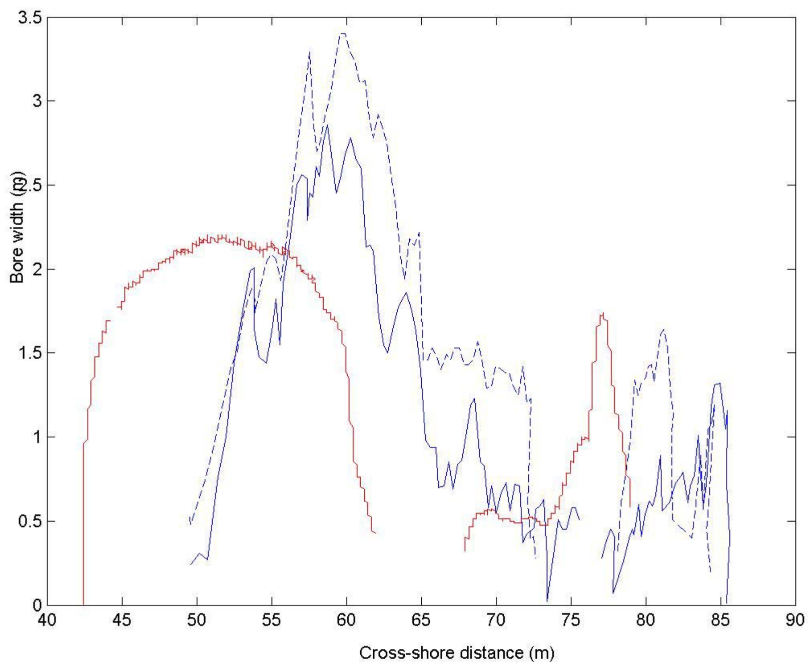

Figure 5: Bore width vs cross-shore distance from phase-averaged observations (solid blue), single tracked wave (dashed blue), and phase-averaged FUNWAVE output (solid red).

IMPACT/APPLICATIONS

There have been very few measurements published of individual breaking wave roller geometries in *shallow water;* as yet, very little is known about the growth, evolution, and decay of this aerated region of white water as it propagates through the surf zone. On the other hand, the roller area and its angle of inclination on the wave front are important quantities governing the dissipation rates in breaking waves. Hence, the wave roller has a dominant influence on the dissipation of wave energy and the balances of mass and momentum in the surf zone. The results of this research will contribute to science in two areas; the first is by leading to improved parameterizations for wave rollers and wave breaking. The second is by providing a better understanding of how remote sensing signals (which are dominated by wave breaking) are related to the hydrodynamic processes of wave breaking. This understanding is crucial before data assimilation techniques can effectively utilize surf zone data.

RELATED PROJECTS

This project is related to two other ONR Coastal Geosciences projects: 1) PI: D. Walker, General Dynamics and 2) PI: R. Holman, Oregon State University. Our results will contribute to the assimilation modeling of D. Walker and will be communicated to him as they become available. R. Holman has provided all the support for the Argus data acquisition and we are actively collaborating.

REFERENCES

Kennedy, A. B., Q. Chen, J. T. Kirby, and R. A. Dalrymple, Boussinesq modeling of wave transformation, breaking, and runup. I: 1D, *J. Wtrwy, Port, Coast., and Ocean Eng.,* 126, 39—47, 2000.

Kirby, J. T., ``Boussinesq models and applications to nearshore wave propagation, surfzone processes and wave-induced currents", in *Advances in Coastal Modeling*, V. C. Lakhan (ed), Elsevier, 1-41, 2003

Van Enckevort, I.M.J. and B.G. Ruessink, Effects of hydrodynamics and bathymetry on video estimates of nearshore sandbar position, J. Geophys. Res., 106, 19,969—16,979, 2001.

Wei, G., J. T. Kirby, S. T. Grilli, and R. Subramanya, A fully nonlinear Boussinesq model for surface waves. Part 1. Highly nonlinear unsteady waves, *J. Fluid Mech., 294*, 71–92, 1996.

PUBLICATIONS

Catalan, P. and M.C. Haller, Nonlinear phase speeds and depth inversion, submitted to Coastal Dynamics ’05.

Catalan, P.A., E. Crawford, and M.C. Haller, Depth inversion using nonlinear dispersion equation and hybrid measurements, AGU Ocean Sciences, Portland, OR, 2004.

Haller, M.C. and P. Catalan, Measurements of shallow water breaking wave rollers, submitted to Coastal Dynamics ’05.

Haller, M., K. Ersson, and P. Catalan, “Shallow Water Wave Breaking (a.k.a. Radar and Argus)”, presented at Argus Workshop, Aug., 2004.

AWARDS

2002 Editors’ Citation for Excellence in Refereeing, JGR-Oceans (awarded Dec. 2003).